REPORT

ON

WESTERN PINE BEETLE STUDIES

CASCADEL UNIT, NORTHFORK, CALIF.

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CASCADEL - 1926

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INTRODUCTION.

This report covers a number of studies and experiments carried on during the season of 1926 on the Cascadel area of the Sierra National Forest. The studies deal principally with the interrelationships between D. brevicomis, and closely related insects, and the western yellow pine.

None of the studies were completed so that this should be considered as a progress report, the aim of which is to put into available form the data so far secured. Though the studies are more or less distinct they are interrelated in that the same trees and equipment were used in a number of the different experiments. Because of this they will all be treated in the one report under separate headings.

General Conditions.

The Cascadel area, in which the experiments were located, includes about four sections in the form of a basin with drainage and principal exposures to the southwest. The elevation is between 3500 and 5000 feet. The stand is fairly typical of the west slope yellow pine type with small percentages of sugar pine, white fir and incense cedar. Several species of oaks, alder and Oregon ash are the principal hardwoods.

The location is almost ideal for experimental studies of this kind, in many respects, but it has one serious drawback in that the western pine beetle infestation is normally quite light and the area never suffers losses as high as are found on many of the southern Oregon and northern California areas. The D. brevicomis losses on the area for the last three years are given on Plate I.

TREE RESISTANCE TO D. BREVICOMIS ATTACKS.

The object of this experiment is to compare the resistance to attack of yellow pine trees of different vigor.

The method used was to cage the base of trees of different vigor, start attacks by forcing the beetles into the caged portion of the trees and then to compare the effect on the different trees.

Former cage experiments.

This method of starting a D. breviconis attack in a yellow pine by use of a cage has been used before in attraction experiments.

Ashland, Ore. Experiment, 1919.

In May, 1919, Miller caged 8 feet of the base of a 22 inch yellow pine with a beetle-tight cage and started an attack by piling D.b. infested bark inside the cage. When the beetles emerged from this bark they could not escape and many of them attacked the tree. Beetles in the vicinity were attracted to the uncaged part of the tree, evidently by these forced attacks, and the entire tree was attacked and killed. The growth rate or vigor of this tree or any evidence of its resistance to attack was not noted.

Jenny Creek Experiment, 1920.

During the summer of 1920 a similar experiment was carried out by J.B. Patterson in the Jenny Creek, Ore. area. In this case the tree used was selected as a tree of average size and growth rate for the area. It was 36 inches in diameter and 150 feet in height. A 12 foot cage of 2 x 4 inch material covered with muslin was used. The first attack was started in this cage on June 10. A number of attacks were made both inside and outside of the cage but all were drowned out by the pitch flow.

DAnother attack was started in this cage on August 5. This attack was successful in attracting a sufficient number of beetles to infest the part of the tree above the cage and the tree was killed. All of the attacks made inside the cage, however, were unsuccessful.

Cascadel Experiment, 1925.

The above experiments were intended only as attraction experiments, but in August, 1925, Miller started an experiment to determine the comparative resistance, to D.b. attacks, of yellow pine trees of different vigor. The details and results of this experiment are given in a "Report of Western Pine Beetle Studies and Experiments on the Cascadel Unit, Northfork, Calif. Season of 1925", by J.M.Miller. In this experiment two trees on the same site and location were selected and caged. One was a very fast growing, vigorous, young tree and the other was a very slow growing overmature tree. A large quantity of D.b. infested bark was piled inside of each cage. The slow growing tree was quickly killed by the beetles which emerged from the infested bark, aided by others which were attracted to the uncaged part of the trunk.

The fast growing tree resisted all attacks made inside the cage though nearly twice as many beetles were released in this cage as in the cage on the slow growing tree.

For some reason the fast growing tree was much less attractive to the beetles flying in the vicinity, as only 20 attacks were made above the cage.

Cascadel Experiments, 1926.

The preceding experiments proved that yellow pine trees vary in their resistance to attacks by D. brevicomis and indicated that fast growing trees offer more resistance to attack than slow growing trees.

This study was continued in 1926 to determine whether or not the resistance of different trees vary directly with their vigor.

Details of the experiment.

Besides the very fast growing tree, Cage tree #2, that resisted attack in the fall of 1925, four other trees were selected with growth rates varying from slow to fast. These four trees were located in pairs with trees 3 and 4 selected to give a comparison of the resistance of a moderately fast growing tree and a slow growing tree; and trees numbered 4 and 6 selected for a comparison of the resistance of a tree of medium growth rate with the resistance of a slow growing tree.

Trees 3 and 4 were located about 50 yards apart on the same site, a good III, trees 5 and 6 about 25 feet apart, also on a site III. All of the trees had a southerly exposure and were at an elevation of about 3800 feet.

The following table gives a comparison of the five trees used in this experiment:

Table I.

	Tree #2	#3	#4	#5	#6
Growth rate	Very fast	Fast	Slow	Slow	Medium
D.b.h.	36"	28"	34"	26"	28"
Height	120'	130'	120'	140'	130'
Crown class	D.	D	D	C	D
" form	Pointed	Pointed	Flat	Round	Round
" length	Long	Medium	Med.	Short	Med.
" width	Wide	Med.	Med.	Narrow	Med.
No. rings in last inch.	5	12	42	29	31
Ring width 1925 in mm.	3.72	2.24	.35	.43	.55
1924	3.30	1.70	.44	.34	.58
1923	7.20	2.75	.77	.68	1.44
1922	4.72	1.12	.52	.44	.83
1921		2.72	.58	.44	.78
" " Av. 1921-1925	4.73	2.10	.53	.47	.84

Description of cages.

On tree #2 the cage used by Miller in 1925 was again used. This was a wire cloth cage on a strip iron frame. The other cages consisted of a wooden frame of 2 x 4 material covered with wire cloth of 16 or 18 strands to the inch. It was found that the 16 mesh screen was practically beetle-tight for D.b. but the 18 mesh is a little safer where an absolutely tight cage is desired.

The screen cage is preferable to the ordinary cloth cage principally because the screen cage allows free circulation of air, thereby maintaining natural conditions of temperature and humidity inside the cage.

On trees 4, 5, and 6 cages 14' in height were used while on tree #3 an 18' cage was used. All of the cages were 4' square so that the 48" screen could be used without making seams except at the corners. See Plate II for a photograph of the cages. This type of cage proved very satisfactory. It is easy to construct and can be taken down and moved from one tree to another.

Procedure.

Bark containing a good brood of the 1925 overwintering generation of D.b. was collected and put in the cages on April 21, 22, and 23, 1926.

A careful record was kept of all events of significance by trees, from the date the bark was put in the cage until the tree had been killed and the brood had emerged.

Observations on the habits of D.b., its predators and other related insects were also made and recorded during the progress of the experiment.

The following table gives the dates of events for each of the trees caged.

Table II.

Dates of Events. 1st Generation Trees.

Tree No.	1st Em. from introduced bark.	1st Att.	Tree overcome	1st fading	1st eggs	1st larvae	1st pupae	1st adults	1st emergence
2	4/24	4/26	Tree successfully resisted all attacks.						
3	4/25	4/29	5/20	6/26	5/25	6/1	6/20	6/27	7/1
4	4/24	4/28	5/7	6/24	5/20	5/26	6/12	6/20	6/25
5	4/24	4/28	5/5	6/20	5/22	5/28	6/15	6/22	6/28
6	4/24	5/5	5/14	6/18	5/25	6/1	6/23	7/1	7/7

The period of heaviest flight and attack was from about May 5, to May 15. The last attack was made by May 20.

With the exception of tree #2 all of the caged trees were quickly killed.

Results:

All of the cage experiments of this kind, so far conducted, go to prove that a D.b. attack may be artificially started on yellow pine trees and that this attack will start an attraction that will usually result in a complete attack and the death of the tree.

Tree #2 - This tree is evidently an exceptional tree as it again resisted all attacks. This in spite of the fact that the number of beetles released in the cage on this tree was as large or larger than the number released in any of the other cages. Hundreds of attacks were made inside of the cage and for awhile it appeared certain that the tree would be overcome. Many of the D.b. even extended their galleries for short distances thru the cambium. But only about 15 new attacks were made above the cage and all attacks both inside and outside of the cage were drowned out.

The reaction of this tree is interesting from the standpoint of both resistance and attraction. Evidently, from the fact that only a few attacks were made outside of the cage, this tree was not as attractive to the beetles in flight as the other trees.

Between July 1st and 20th, during the second D.b. flight period, another attempt was made to kill this tree. The old abandoned bark was taken out and new infested bark was put in the cage. The emergence from this bark was light and only a few new attacks were made inside of the cage and no new attacks were made outside of the cage.

Evidently certain yellow pine of extremely fast growth with thick bark and wide low crowns are both unattractive and highly resistant to D.b. attacks. The protection afforded the trunk by the large heavy crown is probably a factor of some importance in making the tree unattractive.

Comparative resistance of trees 3, 4, 5, and 6.

Although all of the above trees were killed by D.b. they show differences in their reactions that are more or less significant.

The following table compares points [illegible]

Table III.

Tree No.	Growth rate.	No. D.b. liberated per sq. ft.	No. att. per sq. ft.: Inside cage	No. att. per sq. ft.: Outside cage	Em. per sq. ft.: Inside cage	Em. per sq. ft.: Outside cage	Period - 1st A to tree killed.
3	Fast	160	20	18	64	36	19
4	Slow	98	19	13	133	40	9
6	Medium	80	18.5	13	73	51	10
5	Slow	164	15.5	10	84	40	7

The "number of D.b. liberated per sq.ft." column gives the emergence from the introduced bark in terms of the number per sq.ft. of bark on the caged portion of the tree. This number was estimated from counts of a sample 10 sq. ft. from each cage.

The number of attacks and emergence per sq. ft. for the tree itself was determined by counts from strips of bark 1 ft. wide and extending around the trunk. These counts were made for each 10 ft. log for each tree.

The distribution of attacking insects by trees is shown digrammatically on Plate III.

A comparison of the results for trees 3 and 4 brings out three significant differences, evidently the result of the difference in vigor.

1. The period between first attack and the date on which the tree was overcome was over twice as long for the fast growing tree. This in spite of the fact that the number of beetles released in cage 3 and the number of attacks both inside and especially above the cage was considerably larger than for tree #4.

2. The ratio of attacks to emergence, both inside and above the cage indicates greater resistance in tree #3 resulting in a smaller number of successful attacks and unfavorable conditions for brood development.

3. The amount of pitch given off in resisting attacks was over twice as large on the basal 3½ feet of tree #3 as on tree #4. All of the pitch masses for that part of the tree were carefully collected from both trees and weighed.

A comparison of trees 5 and 6 shows less contrast, yet the following points are indicative of greater resistance in tree 6, the faster growing of this pair.

1. The period between first attack and the date on which the tree was overcome was 3 days longer for the fast growing tree.

Tree #6 also showed evidence of being less attractive to D.b. since the period from first emergence to first attack was 11 days for this tree while only 4 days for the other three trees.

2. The ratio of attacks to emergence shows no appreciable difference for the two trees but the fast growing tree showed much more resistance on the caged

part of the tree. All attacks on the basal 10 ft. and the north ½ of the 10 to 15 foot strip were drowned out. On the slower growing tree the attacks were successful except for the basal 5 feet. Tree 6 also had the largest area of unsuccessful attacks between the Ips confusus topkilled part of the tree and the D.b. infested part. See Plate III.

The failure of attacks in most of the caged part of tree 6 may have been partly due to a deficiency of beetles, as this tree had the lowest emergence from the introduced bark of any of the trees. See Table III. If so, this would show that a great surplus of attacking beetles is required, as the largest number of attacking D.b. found in any sq. ft. was 68 while the beetles released in cage 6 amounted to 80 per sq.ft.

Miscellaneous evidence of tree resistance to D.b. attacks.

A number of trees have been found on which D.b. attacks were made but which had successfully resisted these attacks. These trees are exceptional, however, since in spite of the great amount of cruising done only very few such trees are found.

Three trees were found in the 1925 cruise of the Cascadel area that had successfully resisted D.b. attacks. These trees were so heavily attacked that they were marked killed but were later found to be still alive.

In connection with the Cascadel experiments of 1926 a number of attacked trees were not killed. In most cases, it is believed, this was due rather to a shortage of beetles on the area than to the resistance of the trees. This shortage was very noticeable, especially after the first flight period in May. It was found necessary to go outside of the area to find enough infested bark for the experiments.

Conclusions.

D. brevicomis attacks may be started, artificially, on yellow pine trees.

These attacks often start an attraction that results in a complete attack and the death of the tree.

Yellow pine trees vary in their resistance to D.b. attacks.

The data so far secured indicate that the resistance of a tree varies, roughly, with the growth rate; other conditions being equal. The fast growing trees offer the most resistance, the slow growing trees the least.

Certain yellow pine trees are especially resistant to D.b. attacks.

Very fast growth, thick bark and large heavy crowns are evidently factors in this resistance.

ATTRACTION EXPERIMENTS WITH D. BREVICOMIS.

Object: The object of these experiments is to determine the comparative attractiveness of different yellow pine trees and also the effectiveness of certain attractive methods.

1. Caged Tree Experiments.

During the first flight period 6 caged trees were used. (See "Tree Resistance Experiments" for description of trees and cages.) In five of these, trees numbered 2,3,4,5 and 6 the beetles were put into the cages in the brood stage in infested bark so that they would emerge inside of the cage. The results for these trees have already been given. With the exception of tree #2, an unusual tree, a sufficient number of D.b. were attracted to infest the uncaged part of the trunk and kill the tree.

The beetles for the other cage, #8, were allowed to develop and emerge in rearing cages and the adult beetles were put into the tree cage direct. A total of approximately 7000 D.b. adults were put into cage 8 during the first flight period. The caged part of the tree was heavily attacked on the basal 5' with a fair attack up to 8'. But only 2 attacks were made above the cage and all of the attacks failed.

As this tree was smaller than trees 3 or 6 (See Table IV) and apparently more susceptible to attack than either of these trees, that were killed, the reason for the failure of the attack is probably connected with the method and time at which the beetles were introduced and also the number introduced.

It is reasonable to suppose that beetles emerging directly into the cage, on the tree to be attacked, would be in better condition for attack than beetles collected from a rearing cage and transferred to the tree cage. For, although care was exercised, it was noticed that some of the beetles were injured while being transferred. It is also possible that the beetles in emerging from the bark create a small amount of attraction that would be lacking where the beetles were introduced as adults. Another factor, probably of more importance, is the time when and the number of beetles that were introduced. Although 7000 D.b. adults were put into cage 8, during the first flight period, only about 2,500 of them were put in early enough to create an attraction during the height of the flight.

As the bark area of the caged part of the tree is about 60 sq.ft. this would make about 40 D.b. per sq. ft. available for attack during the height of the first flight period. On the cage trees in which the D.b. were introduced in infested bark and allowed to emerge inside of the cage from 80 to 300 D.b. were available for attack per sq. ft.

During the second flight period 3 caged trees were used. The attempt to kill tree #8 was continued and two new trees numbered 20 and 27 were caged. See Table IV for the description of these trees.

Table IV

Description of Trees 8, 20, and 27.

Tree No.	#8	#20	#27
Diameter	20"	18"	20"
Height	110'	110'	100'
Crown class	Intermediate	Intermediate	Intermediate
" form	Rounded	Rounded	Rounded
" Length	Short	Med. short	Medium
" Width	Narrow	Narrow	Narrow
Rings in last inch	28	27	55
Ring width 1926	.93 mm	1.06 mm	.52 mm
" " 1925	1.40	.86	.26
" " 1924	1.11	.88	.07
" " 1923	1.36	1.26	.33
" " 1922	1.00	.86	.25
" " Av. 1922-1926	1.16	.98	.28

Tree #8. - 10,200 more D.b. adults were put in the cage between May 25 and Sept. 10, making a total of 17,200 D.b. released in this cage.

During the height of the flight period between July 1 and July 20 about 50 attacks were made above the cage. No attacks were made above the cage after July 20 and all attacks both inside and above the cage were drowned out.

Tree #27. - 500 D.b. adults were put in this cage on July 8 and 3000 more between August 15 and September 10. About 200 attacks were made inside the cage on the lower 6' of the trunk but no attacks were made outside of the cage. Evidently the attacks made inside the cage created very little if any attraction as no D. b., clerids or other associated insects were seen around the outside of the cage or on the trunk above the cage.

Tree #20 - On July 7 the base of this tree was caged with an 18' cage and 240 sq. ft. of bark with a good brood of D.b., larvae to adults, was piled inside of this cage. There was a heavy emergence from this bark, a total of 21,800 between July 8 and July 20 and a heavy attack, 42 D.b. per sq. ft., was made on the caged part of the tree. This attracted enough beetles to make a good attack above the cage and the tree was killed. The resistance of the tree was overcome in 6 days, between July 10 when the first attacks were made, and July 16 on which date the pitch flow had ceased, egg galleries had been extended as much as 3 inches and egg laying had started.

Summary and Conclusions.

Including the early experiments by Miller and Patterson 9 attempts have been made to start an attack in a tree by caging the base and introducing D.b. infested bark.

With one exception, tree #2, enough beetles were attracted to the tree to thoroughly infest the uncaged part and kill the tree. The exception was a tree obviously unusual in growth rate, size of crown and bark thickness.

Evidently, under reasonably favorable conditions, an attack started in this way (by introducing the D.b. infested bark) will create an attraction that will draw in enough beetles to infest the balance of the trunk and kill the tree.

Two attempts were made to start an attack on caged trees by introducing the D.b. adults direct. An attack was started in both cases but in only one case were D.b. attracted to the uncaged part of the tree and in neither case were enough beetles attracted to kill the tree. This failure to kill either of these trees may be due to (1) the lack of a sufficient number of beetles released in the cages, (2) the small number of beetles on the area, (3) the method of introducing the adult beetles direct, (4) the time, in relation to D.b. flight periods, at which the beetles were introduced or (5) the unattractiveness of the trees used.

The total lack of any sign of attraction about tree #27 shows that even 200 D.b. attacks on a tree does not necessarily create an appreciable attraction.

2. Attraction Thru Piling D.b. Infested Bark at the Base of Uncaged Trees.

Object: to find some method of starting an attack on a selected tree without the use of a cage; and also to determine the attractiveness of a small number of D.b. attacks on a yellow pine.

Method: This method of starting an attack on a tree by piling D.b. infested bark around its base was first used by Miller in the Jackson Experiment in 1923-24. In this case an attempt was made to start an infestation in a small group of young, vigorous yellow pine, partially isolated. A large quantity of infested bark was piled around the base of one of the trees. When the beetles emerged a small percentage of them attacked this tree but most of them left the area and the tree was not killed.

It was thought that the use of this method in an infested area on trees of less vigor would prove more successful.

During the season of 1926, D.b. infested bark was piled around the base of 5 yellow pine trees of different size and growth rate. Approximately the same amount of bark was piled around the base of each tree.

A summary of the important facts about these trees are given in Table V.

Table V.

Tree No.	Date bark placed.	Diam.	Height	Growth Rate	No. of D.b. attacks	Remarks.
13	July 8	30"	130'	Fast	40	Tree severely root pruned 5/11
16	May 13	22"	100'	Medium	Complete attack	Tree killed by 3rd Gen. Att.
30	July 8	26"	120'	Slow	18	Not killed.
32	July 10	20"	80'	Fast	None	
38	" "	16"	80'	"	20	" "

Results:

Of the 5 trees used 4 were attacked by beetles that emerged from the bark pile at its base and in one case other beetles were attracted and the tree was killed.

It was evident that the beetles emerging from the bark made the attacks, and not beetles in flight, as a number were observed while crawling from the bark slabs to the tree and most of the original attacks were made close to the place where the top of the bark pile was in contact with the tree. Where the bark was piled on only one side of the tree most of the attacks were made on that side.

Only a small percent of the total emergence from the bark piles attacked the trees near them. the majority flying away to more distant trees. Many D.b. were observed as they flew away from the bark pile past nearby trees.

The fact that attacks were made on 2 of the 3 fast growing trees used indicates that a number of attacks may be started, even on uncaged trees, regardless of the growth rate. This belief is supported by the results on the Jackson experiment. In that case a number of attacks were made on a young, thrifty tree, growing as fast as any tree in that locality. The growth rate of tree #13 should probably be classed as slow as it had been severely root pruned 2 months before.

The fact that only one of the four trees attacked was killed indicates the lack of a very strong attraction where only a few attacks are made. In the case of tree #16, the one that was killed, the attacks from the beetles emerging from the piled bark were made during the first flight period and though a few beetles were attracted to the upper trunk at that time the tree was not killed until the third flight period; after the tree had been topkilled by Ips confusus and had suffered from about 50 D. valens attacks. It is doubtful if the attacks from the bark pile were responsible for the final successful attacks.

Conclusions.

A number of D.b. attacks may usually be started on a yellow pine by piling D.b. infested bark at the base of the tree.

Only a very small percentage of the emerging beetles attack the tree at which the bark is piled.

Evidently the growth rate of the tree is not an important factor in this study since it is about as easy to get a few initial attacks on a fast growing tree as on a slow growing tree.

The attraction of these few initial attacks is apparently not very great.

The studies so far have been preliminary in nature and should be continued.

3. The Attraction of Transferred Pitch Masses.

This method of starting an attack on a selected tree has been tried by Edmonston and others with some success.

Method: Fresh pitch masses are taken from a newly attacked tree and pressed into the bark crevices of a selected, unattacked tree.

On May 10, 1926, three yellow pine trees were treated in this way with 10 to 15 D.b. pitch masses per tree. The trees used were of medium size and slow growth rate.

Results.

Two of the trees were not attacked.

The other tree was attacked twice. Both attacks were made close to the transferred pitch masses. No later attacks were made and the first attacks were drowned out.

The fact that two attacks were made near the transfered pitch masses indicates that these masses were the source of a small amount of attraction.

The small number of D.b. on this area has been previously noted. Possibly this method would yeild more positive results in an area where the infestation is heavier.

4. The Attraction of Attacks started in Nail Holes.

Object: The purpose of this experiment is also to develop a method of starting an attack on a selected tree and to determine the attractiveness of a few attacks started artificially.

Edmonston found that attacks could be started on yellow pine with D. ponderosae by simply placing the beetles on the trunk of the tree. This method was tried with D.b. on yellow pine without success. A modification, however, suggested by Wagner, gave some interesting results.

Method: Holes about $\frac{1}{8}$" in depth were punched into the bark with a large sized shingle nail and the D.b. adults started into these holes. This method was first tried on a newly attacked D.b. tree and later on an unattacked tree.

Results:

Caged tree #6 - Attacked by D.b. May 5.

On May 14, 12 D.b. adults (both sexes) were started into nail holes punched in the bark above the cage.

On May 17, 6 of these adults had made successful attacks. In a few cases other beetles had been attracted to these holes and were assisting with the gallery construction.

Tree #15 - A slow growing tree 22" in diameter and 90' in height.

Between May 14 and May 20, 20 D.b. adults were started into nail holes. Of these 20, 12 failed to attack and 8 attacked. Those that attacked were drowned out by June 1.

No beetles were attracted to the tree by these first attacks so on July 10, 12 D.b. adults (females) were started into another set of nail holes. By July 12, 4 of these beetles had bored into the phloem and were forming pitch tubes. The other 8 had failed to attack. On this date it was found that a fair attack had been made over the entire trunk of this tree and the tree was killed. The attack had evidently been started shortly after the D.b. adults had started to attack in the nail holes, on July 10. As 3 other nearby trees were attacked at the same time it could not be determined whether or not the attraction from the attacks made in the nail holes were responsible for the general attack over the whole trunk.

Tree #7 - A tree of medium slow growth rate, 19" in diameter and 90' in height.

Between May 15 and May 28, 34 D.b. females beetles were started into nail holes on the trunk of this tree. Of this number 20 were attacked and were drowned out by the flow of pitch and the remaining 14 failed to attack.

Between May 29 and June 8, 20 females and 30 males were started into nail holes on this tree. The two sexes were kept separate so that a comparison of the attacking strength of the two sexes could be made.

14 or 46 percent of the females and only 6 or 20 percent of the males attacked. This is a good indication that the females make a stronger attack than the males. Not only was the number of attacks made by the females higher but the pitch masses formed were much larger also. In one case a female worked for 10 days trying to stop the pitch flow before she was finally overcome.

All of these attacks were drowned out by July 1 and no attacks were made outside of the cage.

Around July 1 about 1000 D.b. were released in the cage on this tree which resulted in a number of attacks inside of the cage. This attracted beetles to the uncaged part of the tree and a fair attack was made for six feet above the cage. The tree was not killed, however, and the attacks were all drowned out.

Conclusions:

Attacks may be artificially started on selected trees by putting D.b. adults into holes made in the bark with a shingle nail.

A fairly high percent of the beetles attack the tree. In this experiment, of 138 beetles put in nail holes on three trees, 58 or 42 percent made attacks.

The females are stronger in attacking than the males. In 60 trials 47 percent of the females attacked as against 20 percent for the males.

Some evidence of attraction from these artificially started attacks was shown. Tree 15 was completely attacked and killed shortly after the nail hole attacks were made. As three other nearby trees were attacked at the same time this evidence is not conclusive.

A number of outside attacks were also made on tree 7. These were not made, however, until after the nail hole attacks were all drowned out and attacks had been started from a number of beetles released inside the cage.

5. Attraction of Topkilled Trees.

It is known that yellow pine trees that are topkilled by Ips confusus are often attacked and completely killed, later, by D. brevicomis.

The purpose of this study was to determine whether or not such topkilled trees are definitely attractive to D.b. and also the percentage of topkilled trees that become D.b. trees.

Method: A record has been kept of every topkilled and D.b. killed tree on the Cascadel unit for the past three years. By a study of these records it was possible to determine the number of topkilled trees that are completely killed later by D.b.

Results: The following table gives the total number and volume of topkilled trees for the three year period and the number and percent of these that are subsequently killed by D.b. See also Plate IV.

Table VI.

Topkilled Trees Subsequently Killed by D.b.

Year of top killing	No. trees.	Total topkilled Volume	Killed by D.b. (1925 and 1926) No. trees.	Volume	Percent of Total
TH (1924) (Winter)	148	226,110	68	97,850	46
TI (1925)	12	19,900	2	3,470	17
TJ (1926)	16	18,610	6	5,810	37
Totals	176	264,620	76	107,130	Av. 43%

The selection by D.b. of 76 out of 176 topkilled trees indicates that the topkilled trees are definitely attractive to D.b.

For this same period, 1924-1926, 629 trees were killed by D.b. of this number 95 or 15 per cent had been previously topkilled.

Studies made by Keen in 1916-17 on the Lambs Mine unit near Ashland, Ore., gave results similar to the above. Out of a total of 192 topkilled trees 51 or 26.6 percent were killed by D.b. within two years.

The average percent of the topkilled trees that were killed by D.b. for these two studies is 35 percent. Since less than one percent of the total number of trees in the stand are selected annually by D.b. it is evident that the topkilled trees are definitely attractive to D.b.

In most cases the trees are killed by D.b. within one year following the topkilling. As an example 68 of the trees topkilled late in 1924 were killed within 2 years. Of this number 65 or 95 percent were killed within the first year.

Summary:

Yellow pine trees topkilled by Ips confusus are evidently quite attractive to D.b.

In the two situations studied 35 percent of the topkilled trees were killed by D.b. within two years. This is in contrast to the number of trees in the total stand that are D.b. killed, which is rarely over one percent annually.

6. General Attraction to a Local Area.

The purpose of this study was to determine whether or not there was a concentration of the D.b. infestation of the Cascadel area onto the experimental area, resulting from the experiments of 1926.

It was thought that the cage experiments and the pruning and cutting of trees might create an attraction that would draw in beetles to the site of the experiments.

Method: The trees killed by D.b. in the summer of 1925 were located and mapped when the area was cruised in the fall of 1925 and the trees killed in the summer of 1926 were mapped when the area was cruised in the fall of 1926. With these records as a basis it was possible to compare the distribution of the infestation before the experiments were started with the distribution after the experiments were started.

The whole area was laid off into zones. Zone 0 includes the three forties in which the experiments were carried on. Zone I includes the 12 forties surrounding Zone 0, Zone II includes the 12 forties surrounding Zone I, Zone III includes the 8 forties surrounding Zone II and Zone IV includes the remainder of the yellow pine area in the Cascadel area. A map of these areas is given on Plate V.

The D.b. summer loss in each of these zones was determined for 1925 and 1926. The results are given in the following table.

Table VII

D. brevicomis loss by Zones for 1925 and 1926, Cascadel Area.

Zone	1925	1926 (x 4.1)	Difference Plus	Minus
		Number of Trees		
0 (x4)	80	180	100	
1	85	65		20
2	52	78	26	
3 (x1.5)	85	50		35
4	72	65		7
		Volume in Bd. Ft. (x 3.56)		
0 (x4)	71,640	98,948	27,308	
1	81,080	90,674	9,594	
2	69,420	82,662	13,242	
3 (x1.5)	99,600	90,322		9,278
4	99,090	75,502		23,588
		Bark Surface Area in Sq. Ft. (x 4.6)		
0 (x4)	26,924	50,104	23,180	
1	26,024	24,573		1,451
2	18,860	24,127	5,267	
3 (x1.5)	31,188	23,585		7,603
4	29,930	24,486		5,444

In 1925 the number of trees killed by D.b. on the Cascadel area was 4.1 times the number killed in 1926, the volume loss in 1925 was 3.58 times the volume loss in 1926 and the loss in terms of infested bark surface area was 4.6 as great in 1925 as in 1926. To make the loss by zones for 1925 comparable with that for 1926 the above figures were used as converting factors. In the table the 1926 loss by trees has been multiplied by 4.1, the volume loss by 3.58 and the loss by bark area by 4.6

Zone 0 includes only 3 forties and Zone 3 includes 8 forties while each of the other three zones include 12 forties. To make all of the zones of equal value the losses on zone 0 were multiplied by 4 and the losses on Zone 3 were multiplied by 1.5 which gives the losses on each of the zones as equivalent to what it would be on 12 forties.

The pronounced increase in the loss in Zone 0 in 1926 as shown in the table represents only the amount of infestation attracted into the area and does not include the infestation brought into the area for the conduct of the experiments. It was estimated that enough beetles were brought into the area in infested bark to attack and kill 5 average sized trees. To eliminate this factor the number of trees killed in Zone 0 was reduced by 5.

It is evident that the bark surface area of the infested trees is the truest index to the amount of infestation and so in Plate VI the amount of infestation is shown in terms of bark area of infested trees.

The pronounced increase in the amount of infestation in Zone 0 in 1926 with a decrease in all of the other zones except one is a good indication of a strong attractive influence in Zone 0.

Conclusions.

The experimental studies of 1926 evidently created an attraction which resulted in an increase in the infestation in the experimental Zone at the expense of the other zones.

This attraction probably extended throughout most of the Cascadel area or for a distance of about one mile.

The exact source of the attraction is not known. It is believed that the forcing of attacks into the caged trees was probably the most important factor.

The increase of the infestation in 1925 on Zone 2, while the zones on both sides showed decreases may be explained by the natural shifting of a certain amount of the infestation from year to year.

7. Attraction to Root Pruned Trees.

The purpose of this experiment was to determine whether or not D.b. would be attracted to root pruned trees.

Two young, fast growing trees were used, numbered 13 and 14. Tree 13 is 30" in diameter and 130' in height, growing on a medium steep slope with a southwest exposure. Tree 14 is a 24" tree, 100' in height, growing on the same slope. The ground cover, principally bear clover, was cleared away for a radius of about 19' and ½ of the total root system of #13 and ½ of the total root system of #14 was cut off on May 11, 1926.

Tree 13 -

24 D. valens attacks were made around the base of this tree between May 11 and June 15. Most of the attacks were made on or near the exposed roots. No. D.b. attacks were made during that period.

On July 8, D.b. infested bark was piled around the base of this tree. Between July 8 and July 15, 40 D.b. attacks were made on the west side of the tree near where the bark was piled and were evidently made by D.b. that emerged from the piled bark. No other insect attacks were made on this tree.

Tree 14 -

18 D.valens attacks were made on this tree between May 11 and July 15. Most of these attacks were made at the base near the exposed roots.

No D.b. attacks were made on this tree.

Conclusions.

Root pruned trees are evidently not attractive to D.b. at least during the first season following treatment. Any later attacks on these trees would probably be the result of the reduced growth rate rather than any attractiveness of the root pruning itself.

As nearby trees were attacked by D.b. after these trees were root pruned the failure to secure attacks was not due to a lack of beetles on the area.

Freshly root pruned trees are attractive to D. valens.

8. Effect of Top Pruning.

Only one tree was used in this experiment, a 16" tree, 70' in height. This tree was young and fast growing with a long, well shaped crown.

The top 20' of the crown and about ⅔ of the remainder of the branches were cut off on May 21.

Two D. valens attacks were made on the base of this tree during the summer but no D.b. or other insect attacks were made.

Tho the results from one tree are insufficient as a basis for any conclusions they indicate a lack of any very definite attraction of D.b. to artificially top pruned trees.

Some attraction to D.v. is shown.

9. Trap Tree Attraction.

Two trap trees, #12 and #39 were cut during the season.

Tree #12 -

This tree was 20" in diameter and 90' in height, located near the top of a ridge with a southerly exposure.

It was felled on May 11 and left uncovered.

May 13 - a few buprestids, an Ips confusus and one D. valens were seen on the top of the trunk.

May 15 - a number of T.n. were seen running about on the top of the trunk.

May 16 - the first D.b. attacks were made.

By May 20 about 100 D.b. attacks had been made. Most of these were made on the north side of the log but some were made on the south side and on the top where partially shaded by limbs.

A light brood developed in the attacked areas.

Tree #39 -

This tree was also 20" in diameter but 110' in height. It was located on a gentle southwest slope.

It was felled on July 20 and covered with brush to protect the top surface from the sun.

By August 13 no insect attacks of any kind had been made and no insects had been seen around the tree. On Sept. 3 a few Ips confusus and buprestid attacks were found.

No. D.b. attacks had been made by Oct., 18.

As a tree within 200 feet of the trap tree was attacked by D.b. after the trap was felled the failure to secure an attack was not due to a lack of beetles on the area.

The results from these two trap trees are fairly typical for trap tree experiments. Where the D.b. infestation is light, trap trees may or may not be attacked depending on the time when cut, the location, and the characteristics of the tree itself. Nearby standing trees are often attacked in preference to trap trees.

10. Attraction to Artificial Lightning Scarred Trees.

This experiment was started by Miller on July 8, 1925. For details see "Report of Western Pine Beetle Studies and Experiments on the Cascadel Unit, Northfork, Calif., Season of 1925".

Four trees were used in this experiment, of which 2 were slow growing and 2 were fast growing. A scar 2½" in width and extending from a point near the top down to the base was made on each tree. Two of the scars were scorched with a blow torch.

During the season of 1925 three of the trees were not attacked by any insect. One of the trees was attacked near the base by a few D.valens. None of the trees were attacked by D.b. As a group of three trees situated within 100' of the experiment were attacked and killed, the failure to get an attack on the scarred trees was not due to a lack of beetles in the vicinity.

These trees were examined again in October, 1926, and all of them were still free from D.b. attacks.

Trees treated in this manner apparently have no attraction for D.b.

THE CLERID, THANASIMUS NIGRIVENTRIS,
Its Life History, Habits and Importance as a Predator of the Western Pine Beetle.

Introduction.

The work previously done on this species by the writer has been covered in two reports, (1) Preliminary Studies on Predaceous Insect Enemies of Dendroctonus brevicomis" dated April 12, 1923, and (2) "Further Studies on Predaceous Insect Enemies of Dendroctonus brevicomis" dated April 7, 1924. These studies were discontinued for two years but were started again as part of the Cascadel Studies of 1926.

Thanasimus nigriventris was selected for intensive study because the results of the preceding studies together with subsequent field observations convinced the writer that this clerid is the most important insect enemy of D.b. at least in the localities studied.

Temnochila virescens chlorodia the other important predator is much less abundant and is less selective in its food habits. D.b. are probably its principal food but it also feeds on wood borers and a number of other secondary insects and even on other predators. (See photo on Plate VII) T. nigriventris, so far as known, feeds normally on no insect except D.b.

Object.

The principal object of the studies of 1926 was to determine by quantitative methods, the effect of T.n. on the D.b. broods under natural conditions. More complete data on the habits and the life history in relation to the life history of D.b. was also desired.

Procedure.

The field studies were carried on in connection with the caging experiments on tree resistance and attraction. Originally it was intended that 14' of the base of two trees of the same site and size would be caged and the trees killed by introducing D.b. adults taken from rearing cages. A large number of clerids were to be put in one of these cages while the other cage was to be kept free from clerids or other predators. Comparative bark counts of the broods and the emergence of D.b. in the two trees would give the effect of T.n. on the developing D.b. broods.

This plan had to be abandoned as the trees were not killed by the D.b. introduced. Instead the following plan was used. On four of the trees caged D.b. infested bark was put in the cages and the D.b. from this bark started an attack which resulted in the death of the trees. It was found that the D.b. emergence from the introduced bark was completed and the tree killed before any emergence of the predators. Taking advantage of this fact all of the bark was removed from the cages as soon as the D.b. had emerged and the caged part of the tree was kept practically free from clerids while the part of the tree above the cage was exposed to the normal action of both the D.b. and the clerids. By comparing the number of T.n. in and the D.b. emergence from a strip of bark around the tree just inside the top of the cage with a similar strip just above the top of the cage the effect of the clerids could be determined.

The study of these four trees was supplemented with bark counts and observations from a number of other trees caged and not caged.

Results.

Table VIII gives the results of the bark counts on trees 4, 5, and 6. The cage on tree 3 was taken down too soon and the number of clerids on the caged area was found to be about the same as on the uncaged part of the tree.

The table is based on counts from two strips of bark, from each tree, only about two feet apart, one just below the top of the cage and the other just above the top of the cage.

Table VIII.

Effect of T.n. on D.b. Broods.

Tree No.	Outside Cage: No. Sq. Ft. Counted	D.b. Att. per sq. ft.	D.b. Em. per sq. ft.	T.n. per sq. ft.	Inside Cage: No. Sq. ft. Counted	D.b. Att. per sq. ft.	D.b. Em. per sq. ft.	T.n. per sq. ft.
4.	7.8	13	42	22	8	19	135	5.0
5.	5.6	10	36	2	6.3	13.5	84	.3
6.	6.3	13	50	5	6.5	18.5	73	1.3

The number of T.n. per sq. ft. of bark was determined by carefully shaving up the bark and counting all of the T.n. larvae, pupae and new adults.

This table can be taken as a fair sample of the results so far obtained. It shows the possibilities of T.n. as a natural control factor and also shows the pronounced variation in their importance in different trees.

The results from the three trees are consistent in that in every case the number of T.n. per sq. ft. was greater and the D.b. emergence was smaller outside of the cage. The differences in the number of T.n. in the three trees are striking, especially as all 3 of the trees are located on the same general area and were killed at the same time. The number of attacks is greater for the area inside of the cage but since the attack over the entire tree was above normal this would probably have little effect on the size of the D.b. brood. Too heavy an attack would cause crowding and a consequent high brood mortality.

Tree #4 shows the great possibilities of the clerids. The uncaged strip, with 22 clerids per sq. ft. had a D.b. emergence of only 42 per sq. ft.; while the caged strip, with only 5 T.n. per sq. ft., had a D.b. emergence of 135 per sq. ft.

Regardless of the difference in D.b. emergence, which may be partly due to other factors besides theclerids, it is evident that 22 clerids per sq. ft. would have a very decided effect on the D.b. broods. Feeding studies showed that large T.n. larvae each destroyed more than .5 D.b. per day while feeding.

It is evident that the beneficial effect of the clerids would also be important in the adult stage. With a D.b. emergence of 42 and a T.n. emergence of 22 per sq. ft. very few of the D.b. would live to attack another tree. (Feeding studies with T.n. showed that each adult might easily destroy between 25 and 50 D.b. adults.)

Tree #4 though considerably above the average is not very exceptional as to the number of clerids in the bark since as many as 30 T.n. were found in one sq. ft. of bark on tree #3 and the average for the entire tree was 17 per sq. ft. 10 to 20 T.n. per sq. ft. were found on a number of uncaged trees that were normally attacked.

Table IX summarizes by trees all of the T.n. counts made in 1926. The T.n. were in any stage from small larvae to new adults or emerged. Egg counts are not included. T.n. that had emerged could be counted by the white, silk lined pupal cells which are made by the prepupal larvae.

TABLE IX

Clerid Counts by Trees - I and II Gen. Trees, 1926.

Tree No.	Generation	No. of Sq. Ft. Counted	Number of Clerids Per Sq. Ft. Min.	Max.	Av. for Tree.
J2	I	4	7	20	13
J3	I	22	10	31	17
J4 (Outside cage)	I	52	6	25	10-
J5	I	53	1	8	4
J6	I	44	3	9	6
Total for Gen. I Trees . . .		155 sq.ft.	Av. for Gen. I Trees . . .		11.6 T.n.per sq.f
J15	II	31	1	9	5
J20(Outside cage)	II	2	6	11	8
J34	II	19	1	5	3
J35	II	28	1	5	4
J36	II	23	3	9	6
J37	II	11	2	20	13
Total for Gen. II Trees . . .		114	Av. for Gen.II Trees . . .		6.5 T.n.per sq.ft.

Total for I and II Gen Trees. 269 Av. for I and II Gen. Trees 8.8 " " " "

These clerid counts give a higher concentration of this predator than any other counts of which we have record. It is not known whether or not 1926 was an unusual year in this respect because we have no other comparative counts. It is evident that on the trees studied the clerids much have been an important factor in reducing the D.b. infestation.

The number of clerids in the Gen. I trees is definitely greater than in the Gen. II trees. This is in support of the belief that there is a decided concentration of the clerids during the early summer. This point will be discussed in connection with the notes on the life history of T.n.

T.n. Life History Notes.

A summary of the data secured on the life history of T.n. is given on Plate VIII. The life history of D.b. is given on the same chart to show the relationship between the two. A few notes on the habits and the location on the tree of the different stages of T.n. are also given. For further details see the two reports refered to in the introduction.

One of the most important points brought out by this study is the overwintering of a certain percent of the clerids as prepupal larvae on 1st and 2nd Gen. D.b. trees. To determine, roughly, what percent of the clerids overwinter on such trees, counts were made during November on four trees, 2, 1st generation trees and 2, 2nd generation trees. The 4 trees were felled and the bark shaved and the clerids counted in a strip, 1 foot wide, around the base of the tree and a strip along the top of the felled tree, 2 feet wide and 30 ft. long.

The strip, around the base was shaved up and examined to determine whether or not the T.n. had migrated to the base as they do in many trees. The results of these counts are given in Table X.

Table X

Number of T.p.

Tree No.	Gen.	Around base Total	Around base Per sq.ft.	Along trunk Sec.#	Along trunk Total	Along trunk Per sq. ft.	Total larvae No.	Abandoned Cells. No.	Abandoned Cells. % of Total
J 64	I	16	2	1 - 63		3.1			
				2 - 11		.6			
				3 - 6		.3			
					80	1.3	6	90	94%
J 147	I			1 - 56		2.8			
				2 - 34		1.7			
				3 - 19		1.-			
		9	1.1		189	1.5	23	95	80%
						Av.percent emerged-Gen.I trees			87%
J 63	II			1 - 39		2.0			
				2 - 28		1.4			
				3 - 9		.5			
		12	1.5		76	1.3	88	0	0%
J 151	II	0	0	1 - 6		.3			
				2 - 11		.6			
				3 - 9		.4			
					26	.4	25	1	4%
						Av.percent emerged -Gen.II trees			2%

Sec. # - These sections were each 2' wide and 10' long. Starting at one foot above the base Sec. 1 reached to 11', Sec. 2 up to 21' and Sec. 3 up to 31'.

A number of interesting points are brought out by this table.

If these trees are representative, from 5% to 20% of the clerids in the Gen. I trees remain in the trees over the following winter and emerge the next spring. Practically 100% of the clerids in the Gen.II D.b. trees overwinter as larvae and emerge the next spring. As many of the clerids in the Gen.III D.b., trees also emerge in the spring or early summer following the attack the result is a distinct concentration of clerids on the Gen. I D.b. trees.

Some migration of the T.n. larvae to the base of trees 64, 147 and 63 is shown. The D.b. broods seldom extend down to the basal foot of a tree and no T.n. larvae would develop in this area, so that any clerids found represent a migration from farther up in the trunk. Actually this migration would be greater than shown because many of the clerids go down into the loose bark beneath the duff where they are difficult to find.

In all of the trees except J 151 the number of T.n. per sq. ft. decreases from Sec. one to Sec. 3. The reason for this is not known.

The number of T.n. per sq. ft. is very small in all four trees. The reason for this is not known but it is possible that many of the prepupal larvae migrated to the base of the tree and were lost in the duff.

Application to Control Work.

The point of principle importance in relation to control work is the concentration of the clerids in the 1st generation D.b. trees. These trees should never be treated by any method that would destroy the clerids because such work might often do more harm than good. Actually, it was found that the summer work in which the first generation trees were treated on the Southern Oregon - Northern California Project, was the least successful of any of the work done. The large number of clerids probably destroyed in this work seems like a reasonable explanation for this lack of success.

THE EFFECT OF THE CERAMBYCID, GRAPHISURUS SPECTABILIS ON THE BROOD MORTALITY OF THE WESTERN PINE BEETLE, D.BREVICOMIS.

Introduction.

It has been known for some time that certain cerambycids effect the development of D.b. broods. Dr. A.D. Hopkins made the following statement in his Bul #83, published in 1909, "The so-called robbers consist of large bark boring grubs or larvae of long horned beetles (cerambycids) which sometimes rob the bark beetle larvae of their food supply or kill them outright by destroying the inner bark before the broods of bark beetles have completed their development."

Studies have been made on the Kaibab during the past two seasons which indicate that Graphisurus spectabilis is of some importance in reducing broods of the Black Hills beetle, (D. ponderosae).

In connection with the Cascadel studies of 1926 Dr. Craighead suggested that some studies be made to determine the effect of this cerambycid on the brood mortality of D.b.

Method.

In this study 4 of the caged trees numbered 3,4, 5 and 6, were used. See "Tree Resistance Studies" of this report, for a description of these trees. They were all killed by the first generation attacks of D.b. in May, 1926.

After the trees had been abandoned by the D.b. broods they were felled and three to five large slabs of bark were peeled from each tree. From each of these slabs 2 sections of bark, each one foot square, were selected; one with the least amount and the other with the greatest amount of inner bark destroyed by cerambycids, for the slab.

This gave a number of pairs of bark sections, both units of each pair selected from the same part of the trunk, but showing the greatest possible difference in the amount of cerambycid work on the inner bark. The D.b. emergence from the two sections from each pair was then compared.

Seventeen pairs of sections or 34 sq. ft. of bark were examined. The results are given in the following table.

Table XI.- Continued

Tree No.	Section No.	Percent of inner bark worked by C.s.	D.b. Em.	D.b. Att.	No. of T.n.	
6	1a	10	46	16		
	1b	65	47	10		
	2a	10	81	15		
	2b	35	52	15		
	3a	5	70	15		
	3b	50	61	16		
	4a	15	48	13		
	4b	40	71	9		
	5a	10	67	19		
	5b	40	52	13		
Av.for Tree 6	a	10	62	16		
	b	46	56	13		
Average for 4 trees.	a (17 sq. ft.	8%	60	14	(17-3 sq.ft.)	
	b (17 sq.ft.	56%	37	12	(22-3 sq.ft.)	

The average results from the 4 trees are shown in graph form on Plate IX.

An examination of Table XI shows that out of the 17 pairs of sections examined, in 14 pairs the D.b. emergence was appreciably higher from the section with the least amount of cerambycid work, in one pair the D.b. emergence was about the same from both sections and in only two pairs was the D.b. emergence less from the sections with the least amount of cerambycid work. The results by trees show that in every case the D.b. emergence was higher from the sections with the small amount of cerambycid work.

The averages for the four trees show that the emergence from the sections with little or no cerambycid work was almost twice as high as from the sections on which the cerambycids had destroyed on the average about 46% of the inner bark.

Since the number of D.b. attacks and the number of predators do not differ materially in the a and b sections it seems evident that Graphisurus spectabilis had an important effect on the brood development of D.b. on the trees studied, with the exception of tree #6.

The above conclusion is reasonable when the habits of this cerambycid is considered. On trees containing very small D.b. larvae, cerambycid larvae were found working in the phloem with the D.b. As the cerambycid larvae were a number of times larger than the D.b. larvae they would naturally destroy large quantities of their food and would probably kill many of the D.b. outright when they happened to get in the way of their (the cerambycids) large mandibles.

The difference in the results in trees studied even where the amount of cerambycid work is the same is probably caused by the difference in the time, in relation to the D.b. brood development, at which the cerambycids begin work. To be of importance they must begin work in the phloem while the D.b. brood is still small and before it has worked out into the outer bark where it is safe from the cerambycids.

Bark thickness is another variable factor that might explain differences in the effect of cerambycid work on D.b. brood mortality.

THE EFFECT OF WOODPECKERS ON A D. BREVICOMIS INFESTATION.

It seems to have been taken for granted that, since woodpeckers are often found feeding on D.b. infested trees, they must be entirely beneficial. In most reports on the western pine beetle the woodpeckers are included as important natural enemies of this insect. There is no doubt but that they destroy a great many D. brevicomis and under certain conditions they are undoubtedly a considerable factor in keeping a D.b. infestation at a low endemic status. But unfortunately the wood peckers show as little selection of the real enemy in their natural control work as we do in our artificial control work, and under certain conditions they evidently do more harm than good.

In connection with the Cascadel studies of 1926 observations were made on three species of woodpeckers which are common to that area; the Harris woodpecker (Dryobates villosus harrisii), the white headed woodpecker, (Xenopicus albolarvatus) and the northern pileated, (Ceophloeus pileatus abieticola).

Of these the northern pileated is probably the most beneficial where it is abundant enough to be a factor. When feeding on D.b. trees it chisels off, with its large, sharp beak, all of the outer half to three quarters of the bark over large areas. Many D.b. infested trees have been found from which 50 to 75 percent of the outer half of the bark has been thoroughly chiseled off. In working on D.b. trees the blows are not struck straight up and down, as is often the case with this wood pecker, when it is working on old logs and snags, but at a tangent so that fairly large pieces of bark are cut off at each stroke.

To determine, roughly the effect of this work on the broods of D.b. and associated insects a study was made of a tree which was one of a group of 4 trees killed by D.b. in July, 1926. This tree was 22" in diameter and 100' in height. Early in August when the D.b. brood was nearly full grown a pair of pileated woodpeckers started work and in a few days they had stripped the outer half of the bark from an almost solid area including the north one-third of the trunk from 16' to 85' above the base.

This tree was felled on August 17 and cut into 10' lengths. From each section counts were made of 2 sq. ft. of bark, one from the side which showed no woodpecker work and the other directly opposite from the side on which only a thin layer of inner bark had been left by the woodpeckers.

The results of these counts are given in the following table:

TABLE XII

Strip No. (Ft. from base)	Sections Without Woodpecker work.		Sections With Woodpecker Work	
	No. of D.b.:	No. of T.n.	No. of D.b. :	No. of T.n.
20	220 per sq.ft.	16 per sq.ft.	16 per sq.ft.	: 6 per sq.ft.
30	135	11	31	5
40	116	20	26	4
50	90	2	14	1
60	86	7	17	2
70	136	9	21	2
Averages	126.8 " " "	10.8 " " "	20.8 " " "	3.5 " " "

D.b. brood in woodpecker worked sections 16% of normal.
T.n. (clerid) brood in " " " 30% " "

The results would naturally vary considerably in different trees and the percent of T.n. destroyed would probably average about the same as the percent of D.b. destroyed. The further developed the broods the greater would be the percent of T.n. killed as they pupate in the outer bark and a very high percent of prepupal larvae, pupae and new (unemerged) adults would be destroyed.

The amount of good done by this woodpecker depends to a large extent on the number of clerids and other beneficial insects which are mixed in with the D.b. broods. Where the number of beneficial insects is proportionately large the woodpeckers would do as much harm as good since they show no selection of the injurious forms.

The work of the Harris and white-headed woodpeckers differs from that of the pileated. These species usually peck almost straight into the bark and dig out the grubs one at a time. In some cases they work the infested bark quite thoroughly, especially if the brood is thick; in other cases they just peck around here and there taking only the insects that may be found just beneath the outer bark scales. In the first instance there is no selection of insects and a stomach examination of a Harris and a white-headed woodpecker, which had been working in this way showed that D.b., clerids, cerambycids and other associated insects both injurious and beneficial were taken indiscriminately. The results of this type of work would be about the same as that for the pileated woodpeckers.

In the latter instance, where only the most easily found insects are taken, there is an unconscious selection of a high percent of clerids, especially in trees where the broods are far advanced. This is because the clerid, T. nigriventris, pupates just beneath the outermost bark scales and so is the most easily found of any of the insects that develop in D.b. infested bark.

This fact became evident when the brood counts were made on trees 4, 5, and 6. (For the description of these trees see the "Tree Resistance" studies of this report.) It was found that on all of these trees there were large areas where T. nigriventris, prepupal larvae, pupae and unemerged new adults, was the only insect taken by the woodpeckers. The D.b. brood, which was farther down in the bark, had not been disturbed. The T.n. that were taken could be easily counted as the prepupal larvae make a white lined cell that is quite conspicuous when exposed.

The results of these counts are given in the following tables:

TABLE XIII

Percent of Clerids Taken by Woodpeckers, Trees 4, 5, and 6.

Tree No.	Strip No. (Ft. from base)	Bark area in sq. ft.	Total No. of T.n.	T.n. taken by Woodpeckers: Number	: Percent of Total
4	10	8.0	39	0	
	20	7.8	175	11	
	30	7.6	157	30	
	40	7.4	145	9	
	50	6.8	117	11	
	60	6.2	111	9	
	70	5.4	84	12	
	80	4.8	41	2	
	90	4.0	24	0	
Totals - Tree #4		58.0	893	84	9.4%
5	20	5.6	13	2	
	30	5.2	26	5	
	40	5.0	40	5	
	50	4.7	24	1	
	60	4.5	17	2	
	70	4.0	8	2	
Totals - Tree #5		29.0	128	17	13.3%
6	12	6.5	8	2	
	16	6.3	31	1	
	26	6.1	54	4	
	35	5.8	36	5	
	45	5.6	37	5	
	55	5.4	23	1	
	65	5.0	24	2	
	75	4.6	20	0	
	85	4.2	19	2	7.9%
Totals - Tree #6		49.5	252	20	7.9%
		136.5 sq.ft.	1273	121	
Totals for Trees 4, 5, and 6					9.5%

Since, on these three trees, the woodpeckers destroyed nearly 10 percent of the beneficial clerids and only a negligible number of D.b. it seems evident that woodpeckers did more harm than good.

It would not be fair to condemn woodpeckers on the basis of such meager evidence and that is not the purpose of this report. Under many conditions, as when the number of clerids and other beneficial insects is proportionately small, the woodpeckers working on D.b. trees would destroy principally D.b. and so do a great amount of good. But it should be recognized that at times their effect on a D.b. infestation may be the opposite of that is desired and expected.

Life History.

The life history of D. brevicomis as worked out in 1926 is shown on Plate VIII together with the life history of T. nigriventris. The D.b. life history is shown in red. In that year there were three generations of D.b. but as the year 1926 had an unusually long growing season it is not known whether or not the rate of development was the same as for other years.

The following table gives the dates for the most important events in the life history of D.b.

TABLE XV.

D.b. Life History Events for 1926 by Generations

		Gen. I	Gen.II	Gen.III
Period of Attack	1st attack	April 25, 1926	June 25, 1926	Aug. 15, 1926
	last "	May 20	Aug. 5	Nov. 1
Egg laying	1st egg	May 5 "	June 27 "	Aug. 20, 1926
	last "	June, 10 "	Sept. 1 "	March 20, 1927.
Larval period	1st larva	May 15 "	July 5 "	Sept. 1, 1926
	Last "	July 15 "	Oct. 1	May 1, 1927
Pupal period	1st pupa	June 5 "	July 25 "	April 1, 1927
	Last "	July 20	Oct. 15 "	June 1, 1927
Adult period	1st adult	June 10 "	Aug. 1, 1926	April 15, 1927
	Last adult	Sept. 1	May 1, 1927	July 1, 1927
Emergence period	1st emergence	June 20 "	Aug. 5, 1926	April 20, 1927
	Ht. of "	July 5-10	Sept. 1 "	May 11-21, "
	Last "	July 30	Sept. 20 "	May 20, 1927

The above dates were taken from records from 10 trees on which very complete records were made, supplemented by less complete data from a large number of other trees. They are quite accurate for the period studied.

The dates for the last half of the 3rd generation were determined in the spring of 1926 and were really the 3rd generation dates for the 1925 broods.

The D.b. brood development periods on the 1926 1st and 2nd generation trees are as follows:

	Gen. I	Gen.II
1st attack to 1st egg	23 days	7 days
1st egg to 1st larva	7 "	8 "
1st larva to 1st pupa	20 "	20 "
1st pupa to 1st adult	8 "	5 "
1st adult to 1st emergence	5 "	4 "
1st attack to 1st emergence	64 "	45 "
1st egg to 1st adult	35 "	34 "

The above periods are based on complete records from 4 first generation trees and 6 second generation trees.

Habits Attack.

It is generally believed that the female makes the initial attack and also extends the egg gallery. The observations of the writer support this belief. About 25 D.b. adults were found just starting an attack and in every case the adult was a female. In the nail hole experiments described under the attraction experiments it was found that although some of the males could be forced to start an attack this number was much smaller than was the case with the females and the attacking male was much more easily discouraged by the flow of pitch. In those cases where 2 beetles were found making an attack together the female usually worked at the innermost end of the entrance tunnel while the male helped work the pitch away from the entrance.

In counts of 7 sq. ft. of bark it was found that of the 68 beetles found at the end of the gallery that was being extended 53 or 78% were females.

Flight Habits of D.b.

1. Flight from a pile of about 125 sq. ft. of D.b. infested bark.

The newly emerged beetles usually crawled about in search of an exposed point before attempting flight. They then spread and folded their wings a number of times and then "took off". In many cases the attempt failed and the beetle fell to theground, crawled back to an exposed point of bark and tried again. When successful the beetle flew off in a north or northeast direction, in the cases observed, at any angle between the horizontal and the perpendicular. The flight could be observed for a distance up to 100' and in every case the beetles flew past the nearby trees with no evident intention of attacking.

The optimum temperature for the beetles was found to be between 70 and 85° F. Beetles moved about actively but normally in the sun at temperatures up to 85° . Many of them made successful attempts to fly.

Between 85° and 95° the beetles were abnormally active and inclined to avoid the full sunlight. Their movements were hurried and attempts at flight were usually unsuccessful.

Temperatures over 95° F. were too hot for the beetles. They avoided the full sunlight and when exposed to it they hurried wildly about and often lost their footing and rolled into a bark crevice. Attempts at flight were usually unsuccessful. One beetle that failed to get out of the sun soon enough became dormant and died in about three minutes at 102°F. in the sun.

The temperatures were taken on the bark surface where the beetles were found, with a corrected eastman thermometer. Since the black beetles would absorb the heat rays of the sun their internal temperature would probably be considerably higher than the temperature at the surface of the bark.

2. Flight to a newly attacked tree.

A number of hours were spent observing the attacking beetles above the cage on tree #5.

Flight to the tree started shortly after sunrise and continued until about sunset. The flight is spasmodic. A number of D.b. would fly to the tree and when they became quite abundant a large number of T. piceriventris would appear both by flight and by crawling from other parts of the tree. This would cause the D.b. to hide in bark crevices and under the bark scales or drop to the ground. Then in a short while the T.n. would disperse and another group of D.b. would fly to the tree. This would continue intermittently throughout the day during the period of flight to the tree if the weather conditions were favorable.

Between 8:30 and 9:00 A.M. on May 14, 14 D.b. flew to this tree and lit inside of an area of about 6 sq. ft. This is about as heavy a flight as was observed during the season. Some of the beetles held onto the bark where they lit while others fell to the ground.

STATISTICAL DATA ON D. BREVICOMIS.

A considerable amount of statistical data was obtained in connection with the experiments already recorded. The taking of this material was incidental to the other work and the results are incomplete.

Ratio of attacks to emergence for Gen. I and Gen. II trees.

	Gen. I (5 trees)		Gen. II (8 trees)	
	No. of Sq. ft. Counted	Av. No. Att. Per sq. ft.	No. of Sq. ft. Counted	Av. No. Att. Per sq. ft.
Attacks	193	14.3	184	10
Emergence (uncaged bark)	140	47	58	44

The number of attacks for both generations is higher than what has been considered normal and the emergence is quite low.

The greater number of attacks on the first generation trees may be due to the ability of the trees to offer more resistance in the spring than in the summer and also to the fact that there was a greater number of beetles in the 1st generation than in the 2nd generation flight.

Misc. Statistics from 1st and 2nd generation trees. (13 trees.)
Counts from sample sq.ft. sections.

Average number of attacks (24 sq. ft.)	12 per sq. ft.
No. of parent adults, total (29 sq. ft.)	24 " " "
No. of parent adults per attack	2 per attack.
Total no. of eggs counted (19 sq.ft.)	5,693
Total length of egg galleries (19 sq.ft.)	1,363 inches
No. of eggs per inch of gallery	4.2
Length of egg galleries per sq. ft. (egg laying completed)	131 (Av. for 4 sq. ft.)
No. of eggs per sq. ft. (egg laying completed)	533 " " " " "

DENDROGRAPH STUDIES

Two dendrographs were used during the season in studies on the diameter variations of trees attacked by D. brevicomis.

The purpose of the studies was to determine some of the reactions of a yellow pine while being attacked and killed by D. brevicomis.

Method.

Two trees, #8 and #20, which were as nearly alike as possible and located on the same site about 50' apart were selected and the dendrographs installed on them. See plate X a and b for photographs of the trees and the dendrographs. The description of the trees are given in Table IV under attraction experiments.

Tree #8 was caged and adult beetles were introduced in order to kill the tree. Tree #20 was left as a check tree to show the diameter fluctuations of a normal tree. But although 17,000 D.b. adults were put in the cage on tree #8 the tree was not killed.

When it was found that #8 would probably not be killed tree #20 was caged and a large quantity of D.b. infested bark was stacked around the tree inside of the cage. The beetles which emerged from this bark together with beetles in flight attacked this tree early in July and killed it.

One of the dendrographs was kept on tree #20 from April 15 to October 10. The other dendrograph was kept on tree #8 from April 15 until September 20 when it was moved to a normal, young, fast growing tree to determine when growth stoped in the fall.

Results:

The results are summarized on Plate XI. The solid line shows the seasonal variations in diameter, slightly smoothed by taking only one point a week, always on the same day of the week. The diurnal variations, shown with dotted lines, are given to illustrate the flattening of the dendrograph curve after a tree is killed.

A comparison of the curves for tree #20 and tree #8 brings out some interesting points. #20 can be considered the normal curve up to July 10. A distinct growth period is shown from May 13 to July 7. On the latter date growth probably stopped for the summer as the beetles did not start to attack until July 10. From July 10 to August 5 there is a rapid shrinkage in the diameter of the tree as well as a marked reduction in the diurnal variation.

Tree #8 shows growth between May 13 and May 20 but during that week about 5,000 beetles were put in the cage and the effects of their attacks is shown, first by the stopping of growth and then by the shrinkage in the diameter of the tree. On June, 10 the tree (#8) had partly recovered and growth is shown up to July 8 when growth probably stopped naturally. The shrinkage from July 8 to September 16 is the result of D.b. attacks.

Curve #8a shows that growth on normal trees probably continued up until October 21 in 1926. There is apparently a period of no growth during most of July, August and September on the dry yellow pine ridges around Cascadel, which is followed by a short period of growth in October before low temperatures stop all growth for the winter.

PLATE I

Course of D. brevicomis Infestation
Cascade Area - 1924-1926

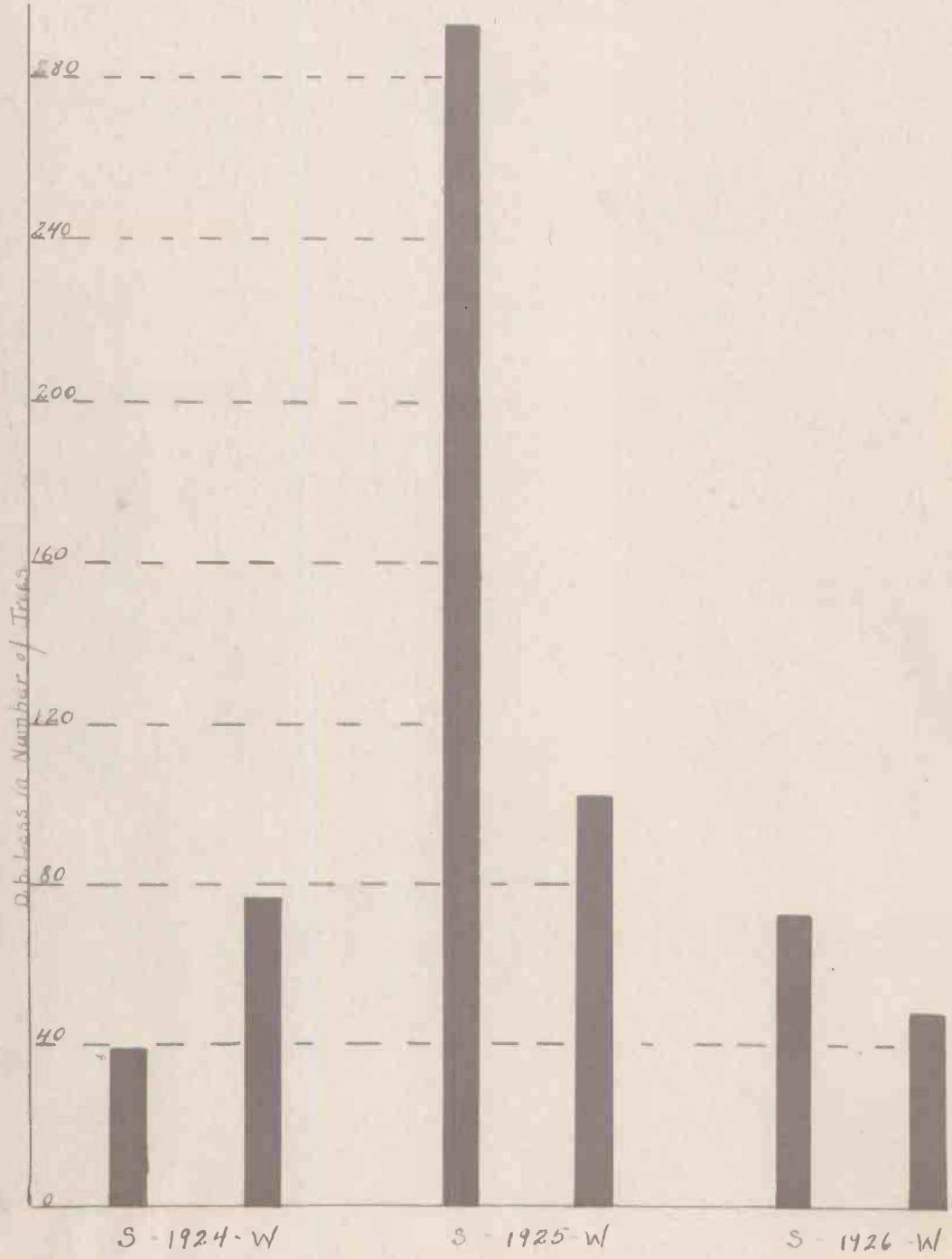

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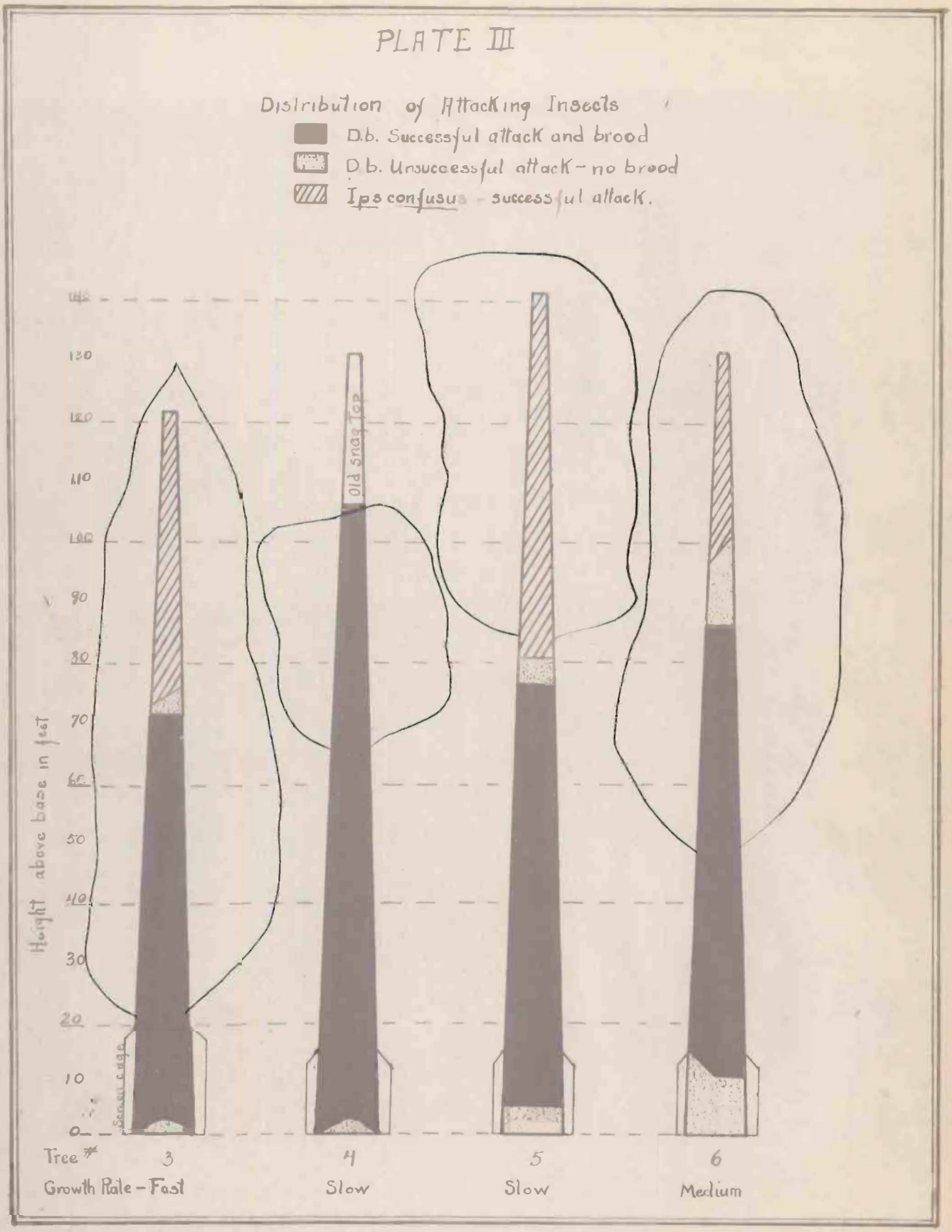
PLATE II.

Photograph of Cages 5 and 6.

Method of piling D.b. infested bark inside of cages is shown.

6169

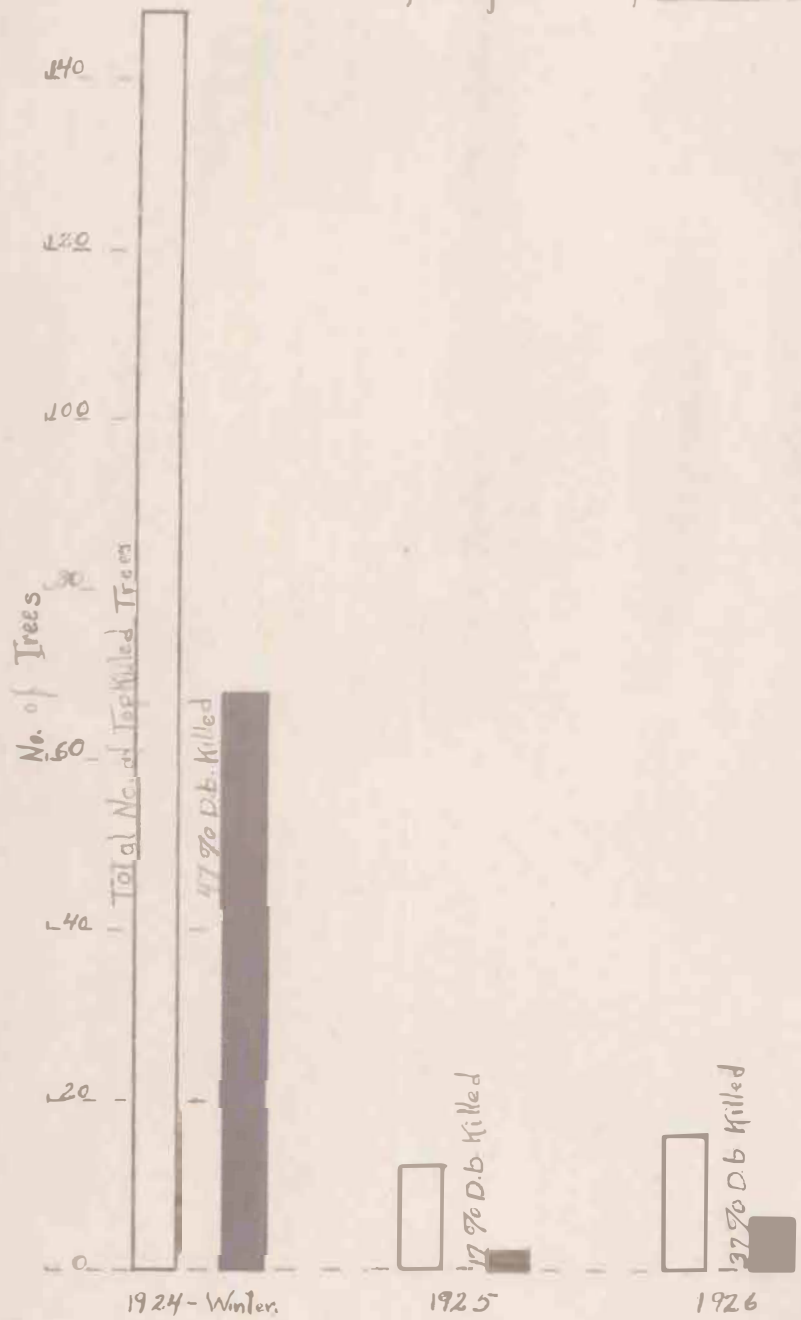
PLATE III



H.L. Person

PLATE IV

Topkilled Yellow Pine
with Percent
Subsequently Killed by D. brevicomis



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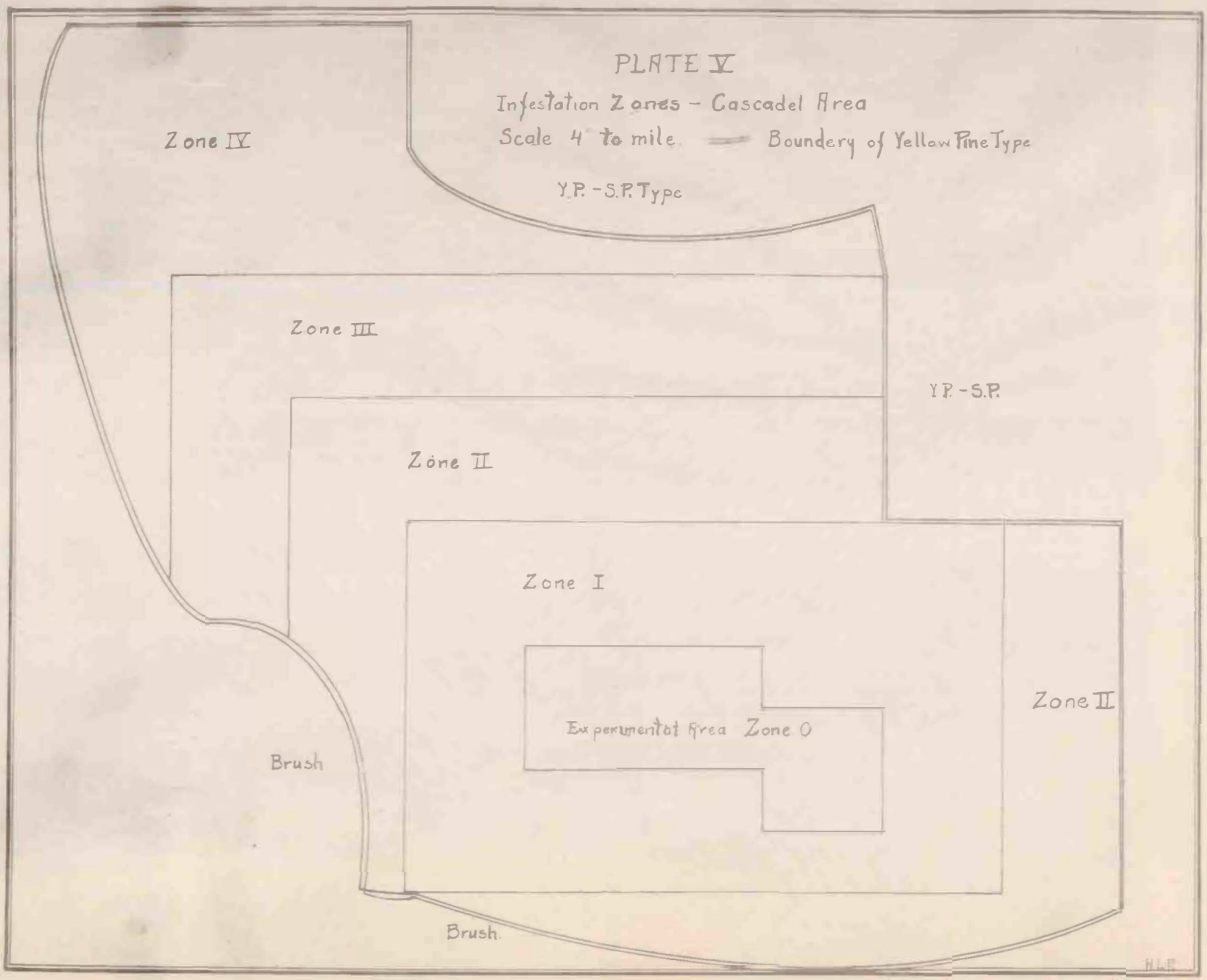
PLATE V
Infestation Zones - Cascadel Area
Scale 4" to mile
Boundery of Yellow Pine Type
Zone IV
Y.P. - S.P. Type
Zone III
Y.P. - S.P.
Zone II
Zone I
Zone II
Experimental Area Zone 0
Brush
Brush

PLATE VI

Distribution of Dbrevicomis Losses
by Zones for 1925 & 1926
Cascadel Area
Loss Shown as Bark Surface Area
of D.b. Killed Trees

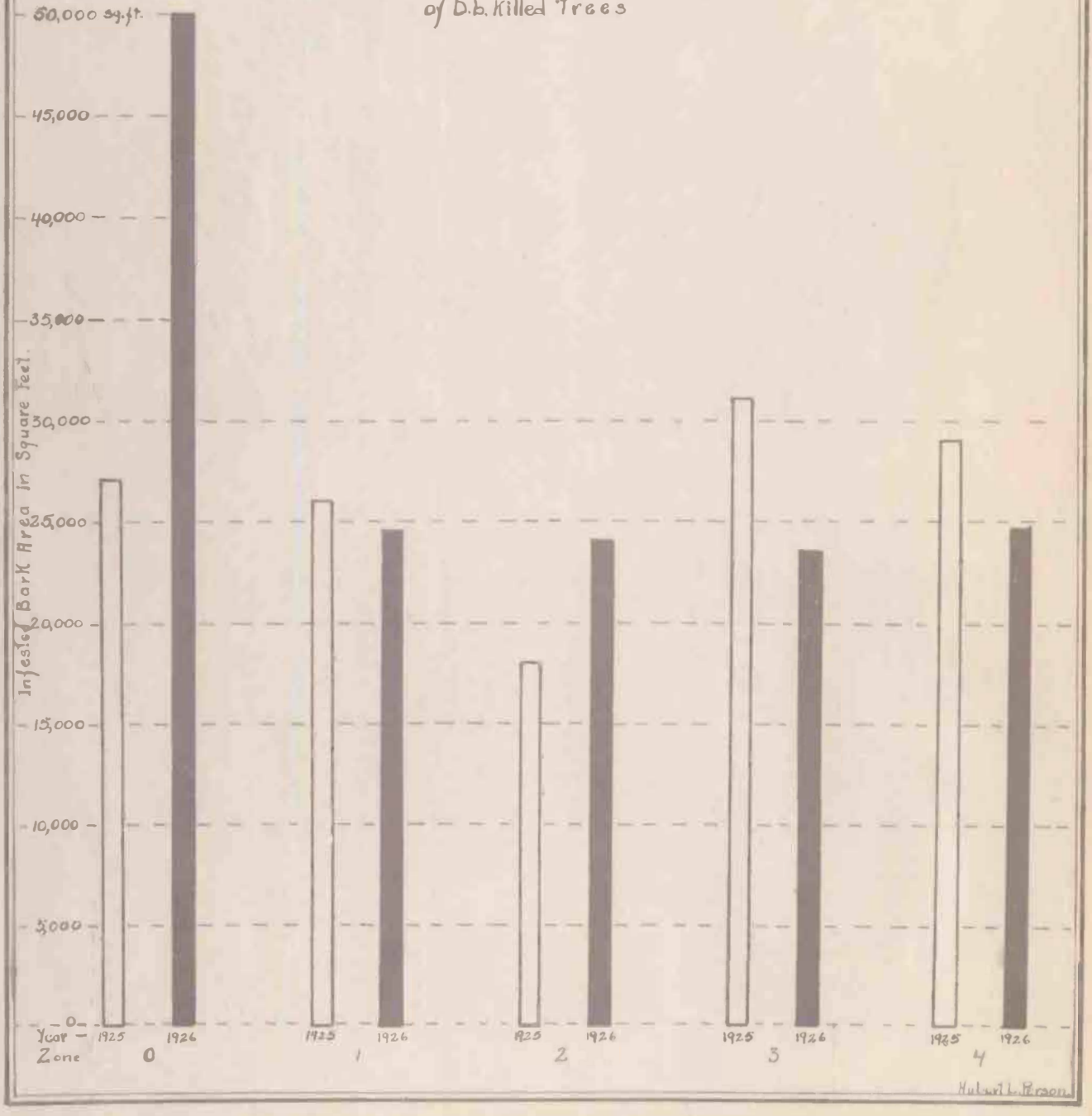

PLATE VII.

An ostomid, Temnochila virescens chlorodia, feeding on the clerid, Thanasimus nigriventris.

The ostomid was found on the trunk of a yellow pine feeding on a living clerid and it kept its hold even after being killed in alcohol.

This photograph, of the preserved specimens, was taken in the laboratory by Duckhorn. Magnified 4 X.

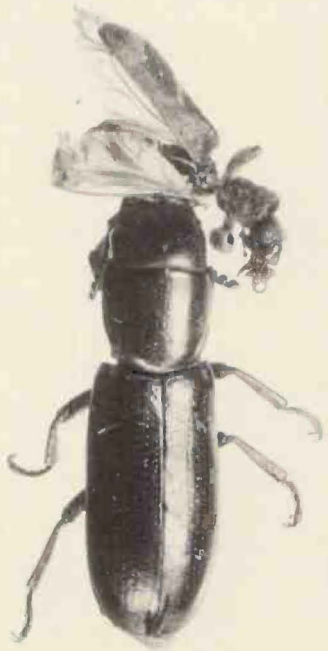

PLATE VIII

A Life History Chart

Showing The Relationship Between

D. brevicomis and The Cerid T. inquirendus

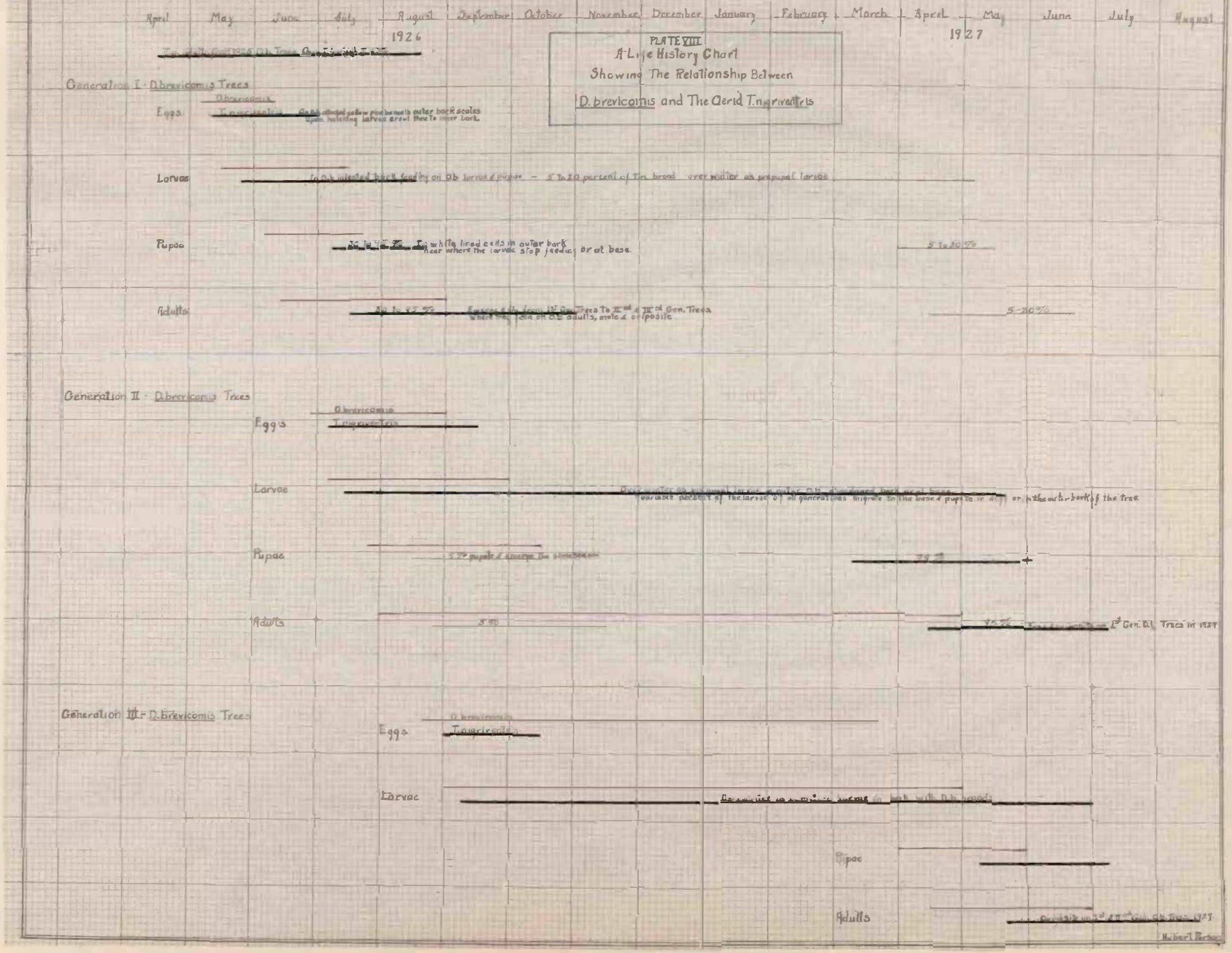

PLATE IX

Relation between Amount of Cerambycid Work & D. brevicomis Emergence

Averages for 4 Trees

■ - Percent of inner bark worked by G. spectabilis

□ D. brevicomis emergence

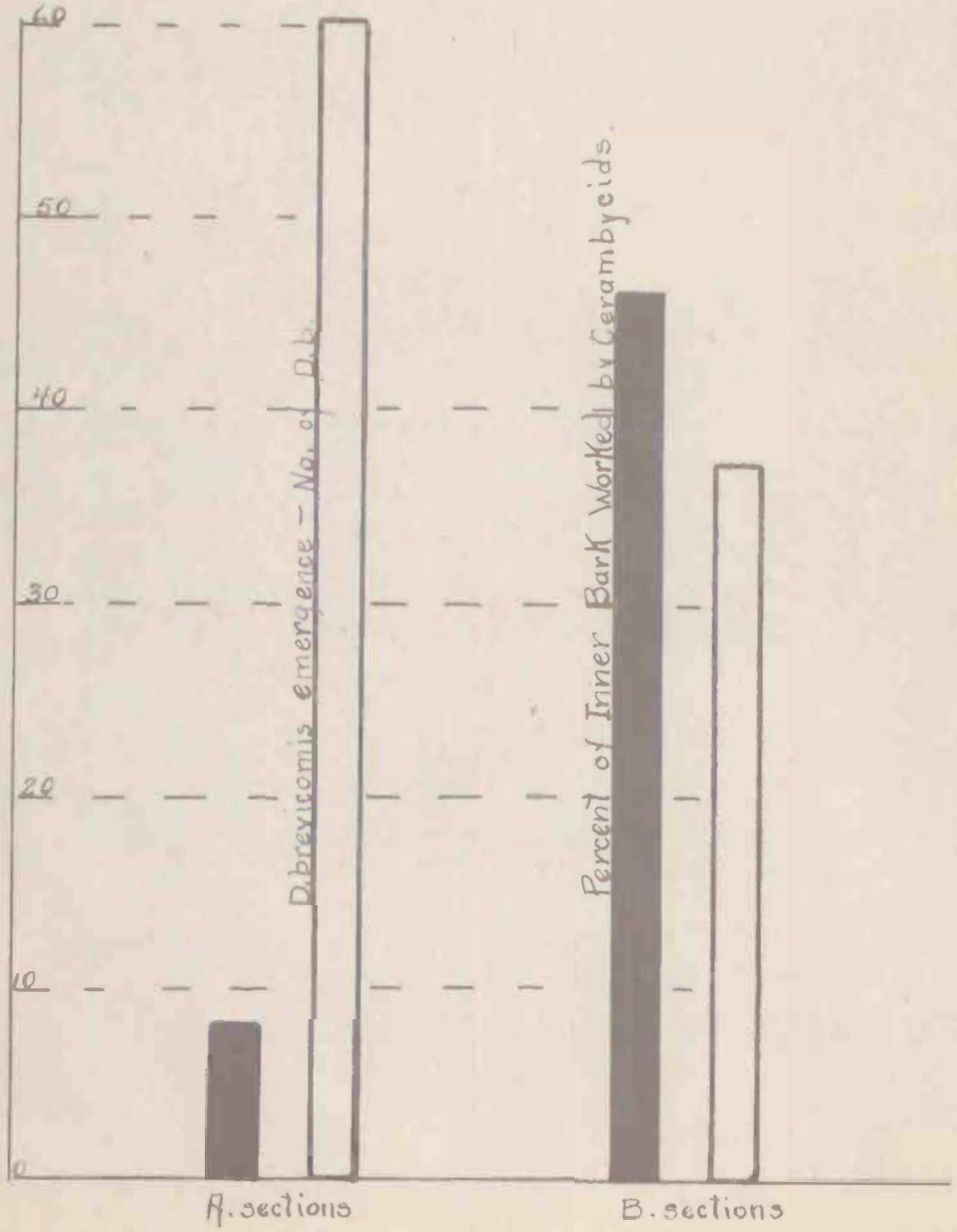

PLATE X a

Dendrograph installed on 20" yellow pine.

PLATE X b.

Dendrograph Trees #8 and #20.

Arrows point to the Dendrographs.

PLATE XI

The Effect of D. brevicomis Attacks on the Diameter of Yellow Pine Trees. As Shown by Dendrograph Records.

Dotted Lines /\ Show Diurnal Variation in Diameter
Air Temperature is Shown in Red

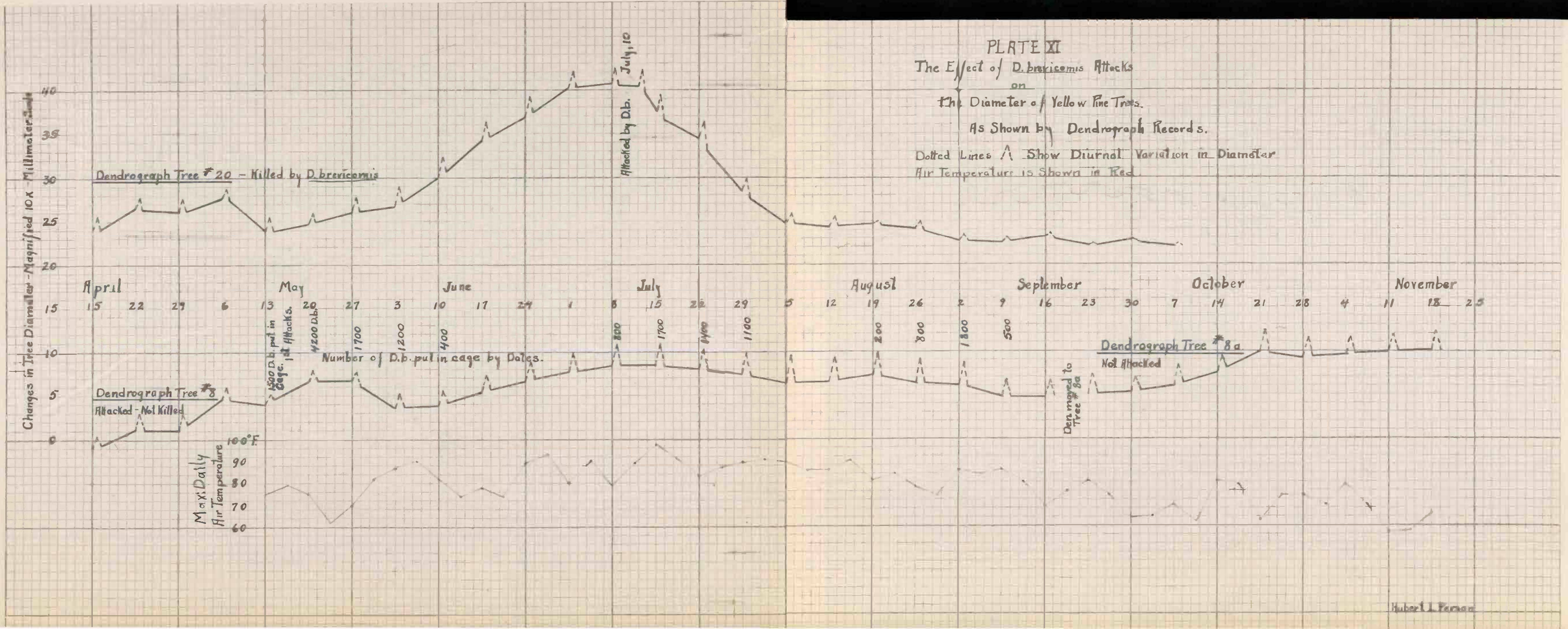

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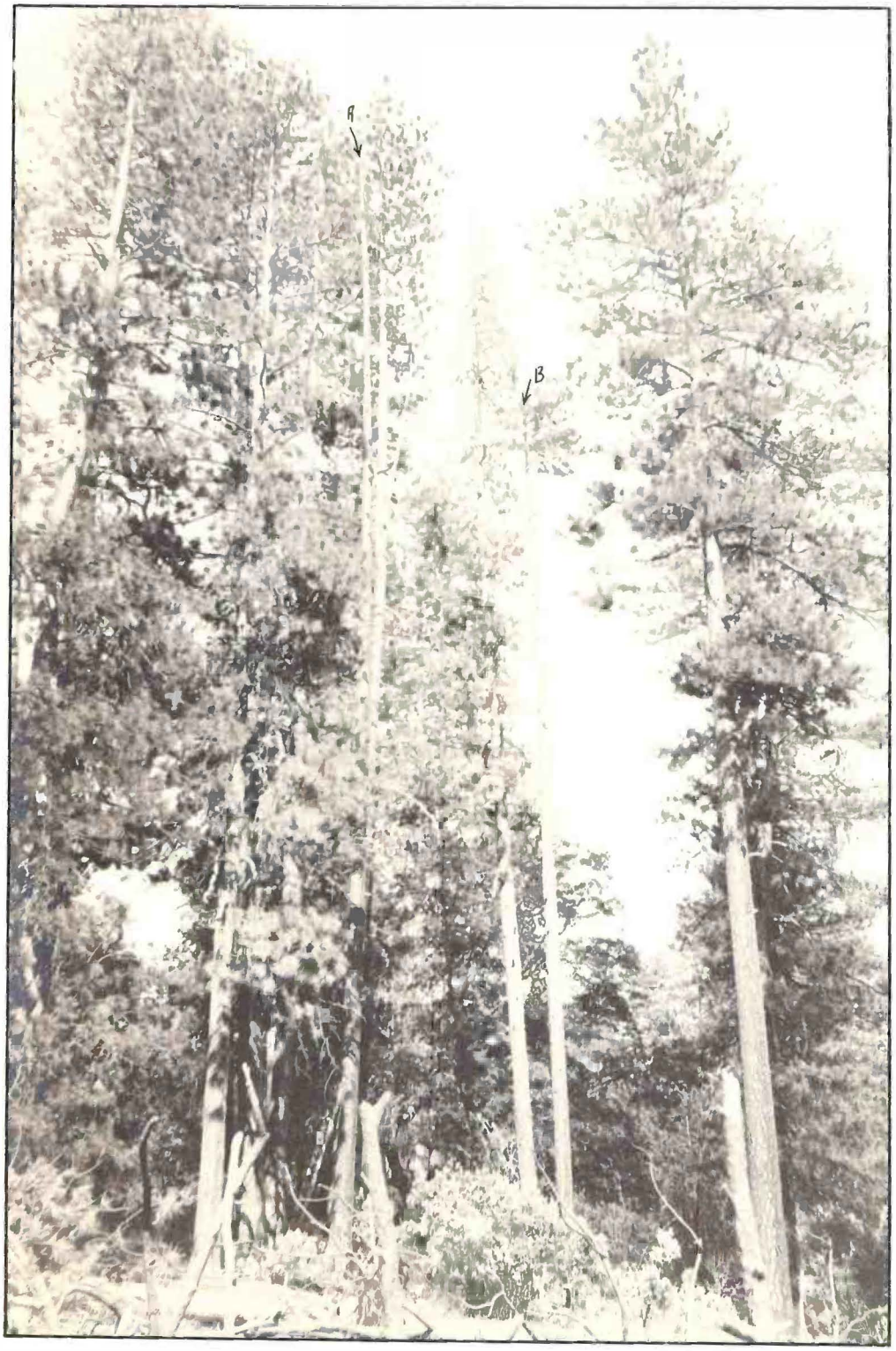
PLATE XII.

Crown pruned trees.

A. - Tree #34 - 100% crown pruned.

B. - Tree #36 - 90% crown pruned.


A
B